NATIONAL RENEWABLE ENERGY LABORATORY

Frito-Lay North America/NREL CRADA

Cooperative Research and Development Final Report

CRADA Number: CRD-06-176

NREL Technical Contact: Andy Walker

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Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI.A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA Number: CRD-06-176

CRADA Title: Frito-Lay North America/NREL CRADA

Parties to the Agreement: PepsiCo (aka Frito-Lay)

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources
Year 1	$ 00.00
Year 2	$ 00.00
Year 3	$ 00.00
TOTALS	$ 00.00

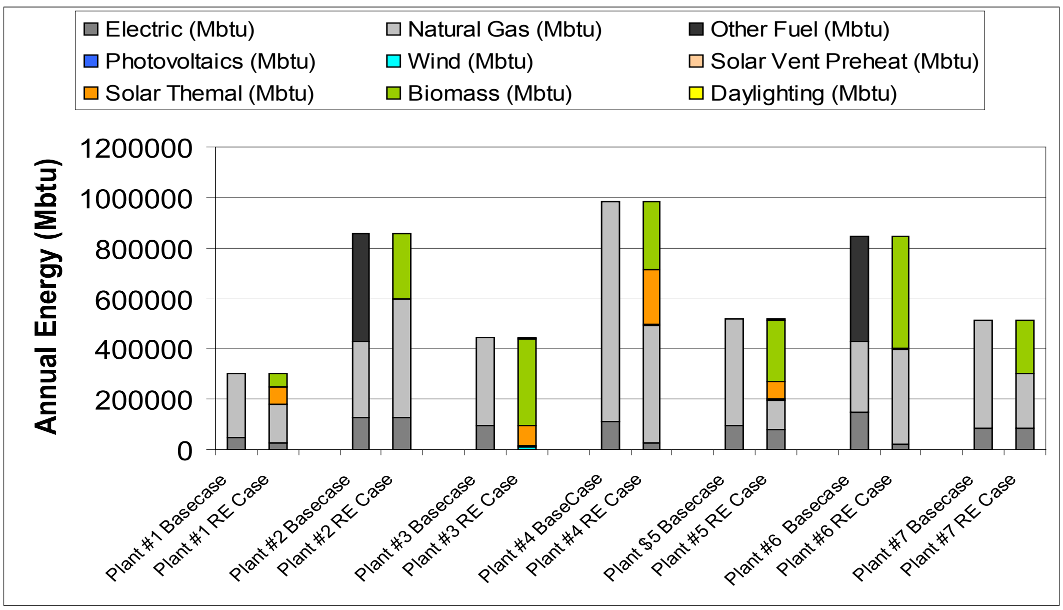
Abstract of CRADA work:

Frito Lay North America (FLNA) requires technical assistance for the evaluation and implementation of renewable energy and energy efficiency projects in production facilities and distribution centers across North America. Services provided by NREL do not compete with those available in the private sector, but rather provide FLNA with expertise to create opportunities for the private sector renewable/efficiency industries and to inform FLNA decision making regarding cost-effective projects. Services include: identifying the most cost-effective project locations based on renewable energy resource data, utility data, incentives and other parameters affecting projects; assistance with feasibility studies; procurement specifications; design reviews; and other services to support FNLA in improving resource efficiency at facilities. This Cooperative Research and Development Agreement (CRADA) establishes the terms and conditions under which FLNA may access capabilities unique to the laboratory and required by FLNA. Each subsequent task issued under this umbrella agreement would include a scope-of-work, budget, schedule, and provisions for intellectual property specific to that task.

Summary of Research Results:

1) Renewable Energy Optimization (REO) Screening of seven Frito Lay plants

This report describes the results of an analysis to determine the combination of renewable energy technologies that minimizes the life cycle cost at seven Frito Lay North America (FLNA) manufacturing plants. The technologies considered include photovoltaics, wind, solar thermal, solar ventilation air preheating, biomass thermal, biomass electric, and daylighting. The FLNA plants considered in the study include: Casa Grande Plant, AZ; Frankfort Core Plant, IN; Jonesboro Plant, AR; Kern Plant, CA; Modesto Plant, CA; Perry Plant, GA; and Topeka Plant, KS. Results indicate that biomass energy could provide steam cost-effectively at many of the plants and solar thermal (concentrating solar) is indicated at the plants in California. Wind power is indicated in Kansas and PV is indicated in California and Arizona due to local incentives. The figure below illustrates how the use of electricity, gas, and coal would be replaced by renewable energy sources at each of the plants.



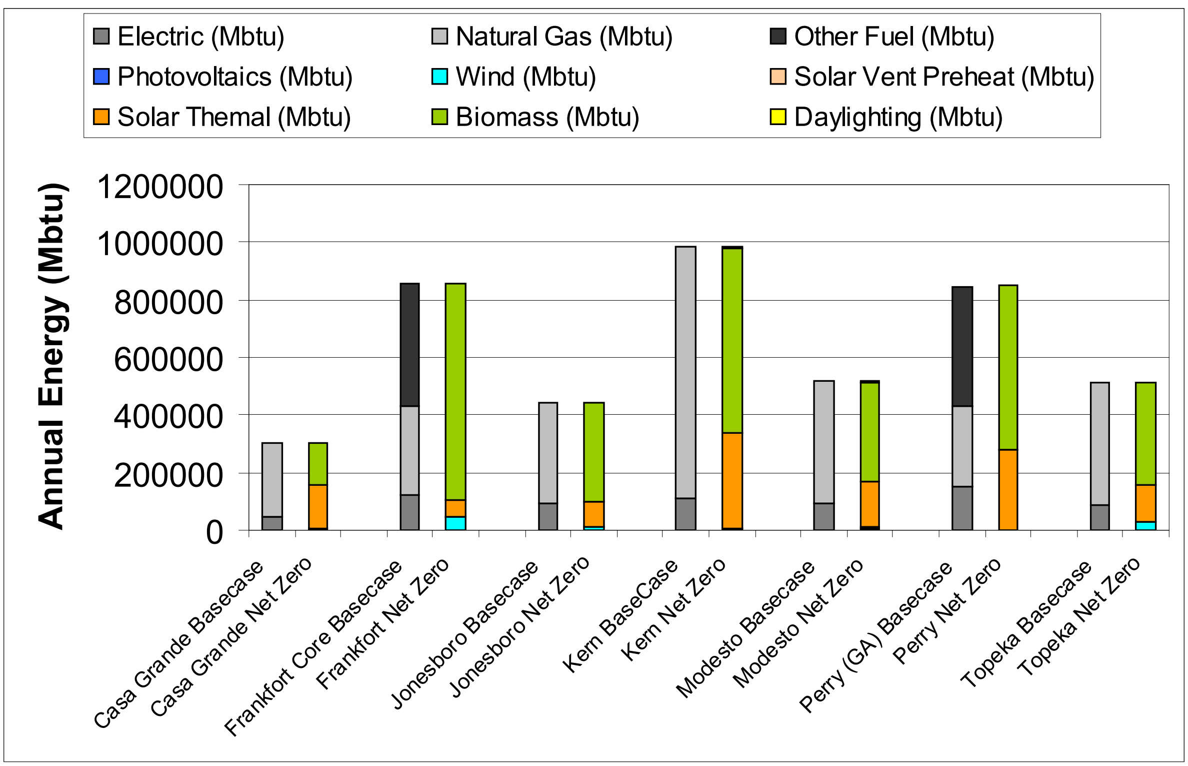
2) Feasibility and Procurement Specs for Modesto Solar Thermal

Frito Lay decided to pursue one of the projects identified in the Renewable Energy Optimization task. A solar industrial process heat plant for Frito Lay Modesto, CA, would include: 5,387 m2 (57,969 sf) of parabolic trough solar collectors; pipe from solar array to unfired steam generator; unfired steam generator (USG); hot water heat exchanger (HWHX); pipe from hot water heat exchanger back to array field; and associated pumps, bypass piping, and controls. NREL prepared a custom computer simulation of the system to predict performance. Results indicate that the system would deliver between 3,898 MWh and 4,308 MWh per year (13.3 and 14.7 billion Btu/year) with an average of 13.8 billion Btu/year. This aligns with previous methods described in the Industrial Process Heat Handbook published by NREL. The simulation is able to model more detail and inform design recommendations, such as bypassing the steam generator and only making hot water on winter days. The following table shows the results of the simulation to calculate one-year's savings.

MONTH	DIRECT NORMAL RADIAION (MBTU)	USG ENERGY DELIVERY (MBTU)	HW HX ENERGY DELIVERY (MBTU)
1	984	1	97
2	1469	11	264
3	2735	295	691
4	3268	554	793
5	4031	987	945
6	4514	1327	961
7	4663	1404	992
8	4388	1178	901
9	3667	841	785
10	3033	426	678
11	1703	32	344
12	1333	0	182
ANNUAL	35788	7056	7633
		TOTAL ENERGY DELIVERY	14689

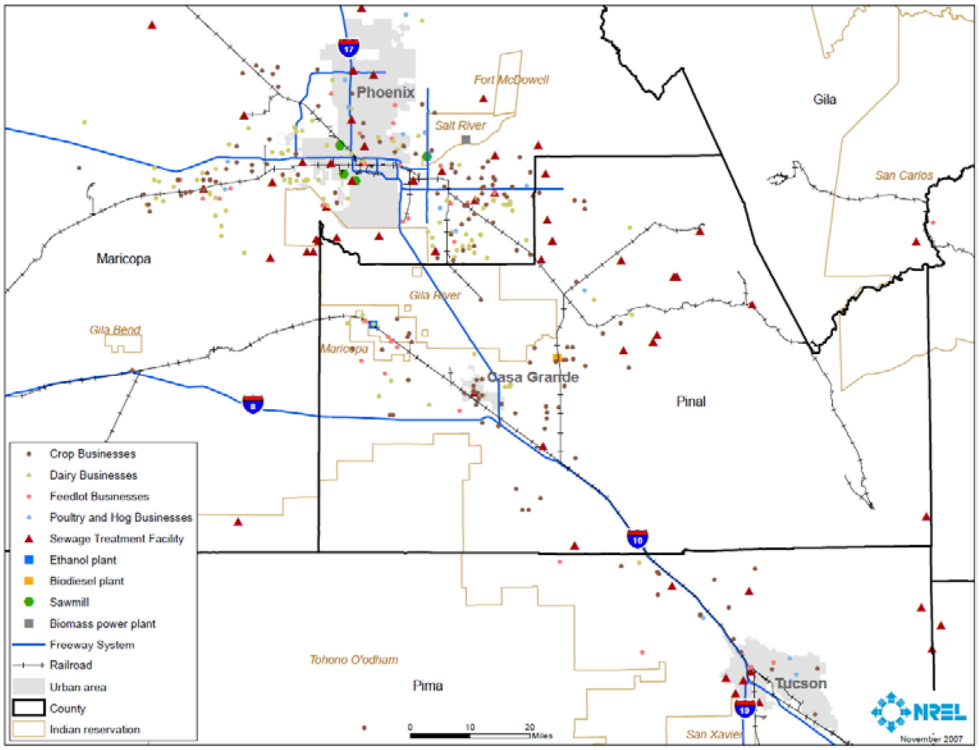
3) REO Net Zero Planning for seven plants

This report describes the results of an analysis to determine the combination of renewable energy technologies that minimizes the life cycle cost of providing 100% of Frito Lay North America (FLNA) manufacturing plants' energy on an annual basis. The technologies considered include photovoltaics, wind, solar thermal, solar ventilation air preheating, biomass thermal, biomass electric, and daylighting. The FLNA plants considered in the study include: Casa Grande Plant, AZ; Frankfort Core Plant, IN; Jonesboro Plant, AR; Kern Plant, CA; Modesto Plant, CA; Perry Plant, GA; and Topeka Plant, KS. Results indicate that biomass, solar ventilation air preheating, and daylighting are part of the least-cost mix at all plants, while photovoltaics, wind, and solar thermal depend on local resources and incentives. The basecase of continuing to purchase electricity, gas, and coal has zero initial cost but high annual cost, while the Net Zero case has high initial cost but low annual cost. Over a 25-year analysis period, the life cycle cost of the two alternatives is very similar, but the Net Zero case has a slightly higher life cycle cost in all seven plants considered, ranging from 3% higher for Jonesboro, AR, to 19% higher for Frankfort, IN. The figure below illustrates how the use of electricity, gas, and coal would be replaced by renewable energy sources in a Net Zero Plant.



4) Detailed biomass assessment and Net Zero Charrette for Casa Grande, AZ Plant

In further support of the net zero plant project in Casa Grande, Arizona, NREL provided consultation on biomass resources and conversion technologies for converting local agricultural residue (pecan hulls) into energy for steam and electricity. The following figure shows NREL GIS information regarding the locations of pecan hulls in the area of the plant.



5) Performance Evaluation of Installed Modesto Solar Thermal Project.

This report describes results of field monitoring and simulation provided by the National Renewable Energy Laboratory in support of a 54,000 sf solar thermal plant at Frito Lay facility Modesto, CA, under Cooperative Research and Development Agreement 06-176. The following table presents the results of simulation and field measurements of peak solar field performance. While less than the peak delivery of the Design Case (9.6 million Btu/hour), the measured (extrapolated from measurement) peak delivery after cleaning and alignment of 8.1 million Btu/hour is within the range of performance promised by the supplier (8 million Btu/hour).

Peak Performance of Solar Collector Field

Fit Label	*Reference Conditions:* I_b *= 1000 W/m²* *□i= 0 deg* *□T = 200 °C*		*Peak Modesto Conditions:* I_b *= 872 W/m²* *□i= 13 deg* *□T = 200 °C*		*Measured Conditions:* I_b *= 575 W/m²* *□i= 45 deg* *□T = 90 °C*	
	(kW)	*(MBtu/hr)*	*(kW)*	*(MBtu/hr)*	*(kW)*	*(MBtu/hr)*
Design Case (Sandia)	3310	11.3	2810	9.6	1880	6.4
Before Cleaning and Align2	1930	6.6	1610	5.5	1080	3.7
After Cleaning and Align	2810	9.6	2370	8.1	1440	4.9

Annual Energy Delivery is expected to be less than the design case value of 13.7 billion Btu/year because of several items listed in the table below. A thermodynamic model of the system (hourly simulation) was used to model the effects of each of these differences from the design case. Based on the current configuration, annual energy delivery may be estimated at 9.85 billion Btu/year after cleaning and alignment.

Annual Performance of Solar Collector Field

	Annual Energy Delivery (billion Btu/year)
Design Case	13.70
No Hot Water Heat Exchanger (HWHX)	11.79
Add 90 lb Steam Header	12.76
3840 ft of pipe instead of 2400 ft	11.80
Tracking 67 deg instead of 79 deg.	9.85
Dirt 9% loss instead of 3% loss	8.92
7% loss correctable by alignment	7.61

Subject Inventions Listing: No inventions reported.

Report Date: 3/20/2013 **Responsible Technical Contact at Alliance/NREL**: Andy Walker

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